CALCULATION OF NO_x EMISSIONS REDUCTION FROM IMPLEMENTATION OF THE 2000 IECC/IRC CONSERVATION CODE IN TEXAS

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ABSTRACT

Four areas in Texas have been designated by the United States Environmental Protection Agency (EPA) as non-attainment areas because ozone levels exceed the National Ambient Air Quality Standard (NAAQS) maximum allowable limits. These areas face severe sanctions if attainment is not reached by 2007. Four additional areas in the state are also approaching national ozone limits (i.e., affected areas)[1]. In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to reduce ozone levels by encouraging the reduction of emissions of NO_x by sources that are currently not regulated by the state[2]. An important part of this legislation is the State's energy efficiency program, which includes reductions in energy use and demand that are associated with the adoption of the 2001 IECC[3], which represents one of the first times that the EPA is considering emissions reductions credits from energy conservation – an important new development for building efficiency professionals, since this could pave the way for documented procedures for financial reimbursement for building energy conservation from the state's emissions reductions funding. This paper reviews the procedures that have been used to calculate the electricity savings from residential construction in non-attainment and affected counties. Results are presented that show the annual electricity savings and NO_x reductions from implementation of the 2001 IECC to single family residences in 2002, which use the DOE-2 simulation program.

BACKGROUND

The Federal Clean Air Act of 1970 authorized the United States Environmental Protection Agency (EPA) to establish the maximum allowable concentrations of pollutants that are known to endanger human health, harm the environment or cause property damage. In response to this act the EPA established NAAQS which describe the allowable maximum limits of the six primary pollutants: carbon monoxide (CO -- 9 ppm, 8 hr avg.), lead (Pb -- 1.5 ppm, maximum quarterly average), oxides of nitrogen (NO_2 -- 53 ppb annual average), Ozone (O_3 -- 120 ppb, 1 hr, avg.), particulate matter (PM_{10}-- 50 micrograms/m^3 annual average), and sulfur dioxide (SO_2 -- 30 ppb annual average). In Texas the Texas Commission on Environmental Quality (TCEQ) has the responsibility of measuring and reporting these emissions to the EPA.

Nationally, areas that exceed safe levels of Ozone are carefully monitored by the U.S.E.P.A. Ozone is formed when oxides of nitrogen (NO_x), volatile organic compounds (VOCs), and oxygen (O_2) combine in the presence of strong sunlight. Hence, controlling NO_x emissions is fast becoming a priority for many areas of the United States as indicated in Figure 1, which shows that NO_x emissions can vary significantly from one county to the next, even in states where the state-wide average is moderate. For example in 1994, according to the EPA, Texas ranked #1 in NO_x production with 2,611,000 tons/yr of NO_x annually[4], yet because of its large geographic area,

[1] The non-attainment areas include: Beaumont-Port Arthur, El Paso, Dallas-Ft. Worth, and the Houston-Galveston-Brazoria area. Affected areas include: Austin, Corpus Christi, San Antonio, and the Longview-Tyler-Marshall area.

[2] The state agency responsible for emissions reductions is the Texas Commission on Environmental Quality (TCEQ). Prior to August 2002, this agency was the Texas Natural Resources Conservation Commission (TNRCC).

[3] The "2001 IECC" notation is used to signify the 2000 International Energy Conservation Code (IECC 2000) as modified by the 2001 Supplement (IECC 2001), published by the ICC in March of 2001, as required by Senate Bill 5.

[4] This 2,611,000 tons/yr is estimated to come from the following sources: electric utility power plants (716,000 tons/yr, 27%), on-road mobile (540,000 tons/yr, 20.7%), industrial point sources (766,000 tons/yr 30.7%), non-road

Texas is only considered an average NO_x emitter per square mile (upper map in Figure 1). However, in the fast growing metropolitan areas of Texas, NO_x emissions by county exceed safe levels (lower map in Figure 1), with 27% (716,000 tons/yr) of the NO_x pollution coming from utility power plants that provide electricity to Texas.

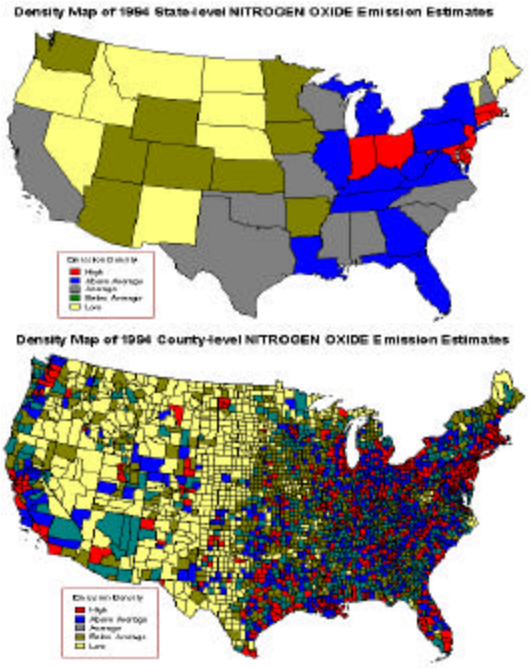

Figure 1: *1994 USEPA State and County-level NO_x Emissions Estimates (USEPA 2003).*

In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to further reduce ozone levels by encouraging the reduction of emissions of NO_x by sources that are currently not regulated by the TNRCC, including area sources (e.g., residential emissions), on-road mobile sources (e.g., all types of motor vehicles), and non-road mobile sources (e.g., aircraft, locomotives, etc.)[5]. An important part of this legislation is the evaluation of the State's new energy efficiency programs, which includes reductions in energy use and demand that are associated with specific utility-based energy conservation measures, and implementation of the International Energy Conservation Code (IECC 2001). In 2001 thirty-eight counties in Texas were designated by the EPA as either non-attainment or affected areas. These areas are shown on the map in Figure 2[6].

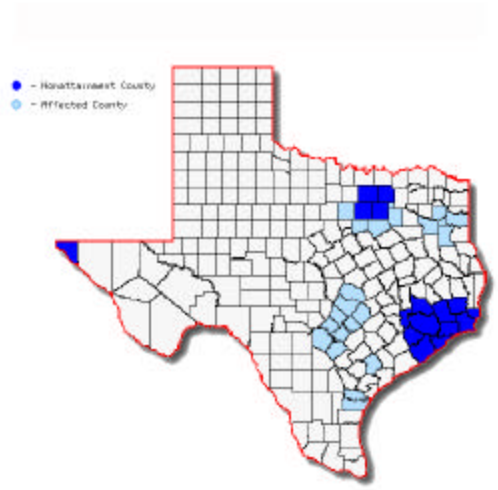

Figure 2: *EPA Non-attainment (blue) and affected counties (light blue).*

These counties represent different areas of the state that have been categorized into the different climate zones[7] contained in Chapter 3 of the 2001 IECC as shown in Figure 3. Also shown on Figure 3 are the locations of the various weather data sources, including the seventeen Typical Meteorological Year (TMY2) (NREL 1995), and four Weather Year for Energy Calculations (WYEC2) (Stoffel 1995) weather stations, as well as the forty-nine National Weather Service weather stations, (NWS) (NOAA 1993). To no surprise, these thirty-eight counties represent some

sources (366,000 tons/yr, 14.0%), other combustion sources (34,000 tons/yr, 1.3%), and other sources (189,000 tons/yr, 7.24%) (USEPA 2003).

[5] In the 2003 Texas State legislative session, the emissions reductions legislation in Senate Bill 5 was modified by House bill 3235, and House bill 1365. In general, this new legislation strengthens the previous legislation, and did not reduce the stringency of the building code or the reporting of the emissions reductions.

[6] The sixteen counties designated as non-attainment counties include: Brazoria, Chambers, Collin, Dallas, Denton, El Paso, Fort Bend, Hardin, Harris, Jefferson, Galveston, Liberty, Montgomery, Orange, Tarrant, and Waller counties. The twenty-two counties designated as affected counties include: Bastrop, Bexar, Caldwell, Comal, Ellis, Gregg, Guadalupe, Harrison, Hays, Johnson, Kaufman, Nueces, Parker, Rockwall, Rusk, San Patricio, Smith, Travis, Upshur, Victoria, Williamson, and Wilson County.

[7] These climate zones include Zone 5 or Zone 6 (i.e., 2,000 to 2,999 HDD_{65}) for the Dallas-Ft. Worth and El Paso areas, and climate Zones 3 and 4 (i.e., 1,000 to 1,999 HDD_{65}) for the Houston-Galveston-Beaumont-Port Author-Brazoria area.

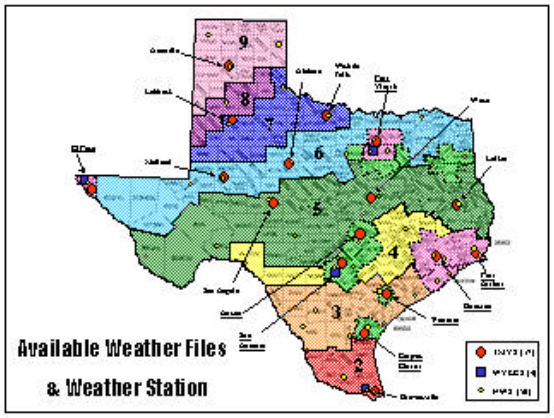

Figure 3: *Available NWS, TMY2 and WYEC2 weather files compared to the 2000 IECC weather zones for Texas.*

of the most populated counties in the state, and contained 13.9 million residents in 1999, which represents 69.5% of the state's 20.0 million total population (U.S. Census 1999). As shown in Figure 4, three of these counties (i.e., Harris, Dallas, and Tarrant), are non-attainment counties. The fourth county, Bexar county, is classified as an affected county. These four counties contain 8.0 million residents, or 40.0% of the state's total population. In the rankings of the remaining counties it is clear to see that the most populated counties also represent the majority of the non-attainment regions.

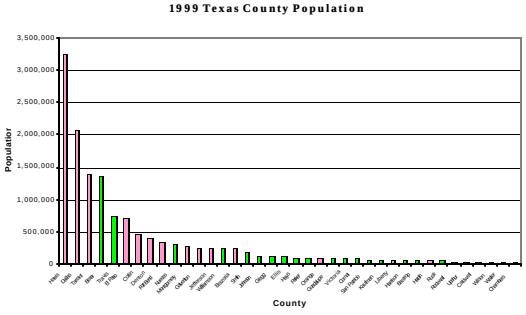

Figure 4: *1999 Texas county population for non-attainment (pink) and affected (green) counties (Source: U.S. Census)*

In Figure 5 the total housing units in the non-attainment and affected counties is shown to closely follow the county populations, with Harris, Dallas, Tarrant, and Bexar counties containing 3.2 million housing units, or 40.0% of the state's total 8.0 million households (U.S. Census 1999). However, in Figure 6 the 1999 residential building permit activity is shown that differs from the population and total housing unit trends, with the most activity occurring in Harris county (25,862 units), followed by significantly less construction in the five counties in the 10,000 to 15,000 unit range, including Dallas, Travis, Bexar, Collin and Tarrant counties. These six counties represented 88,833 housing starts, or 71% of the total 125,100 residential building permits in the 38 counties classified as non-attainment or affected by the EPA. Also of interest in Figure 6 is the significant number of new multi-family units in the counties with the largest number of building permits[8]. In the six largest counties (i.e., Harris, Dallas, Travis, Bexar, Collin and Tarrant) there were 34,038 new multi-family units, or 38% of the 88,833 housing starts in these counties.

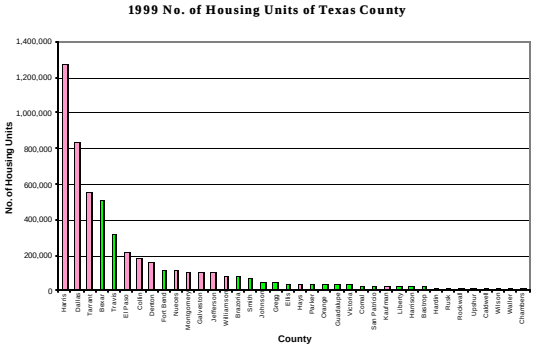

Figure 5: *1999 Housing Units by County (Source: RECenter 2002).*

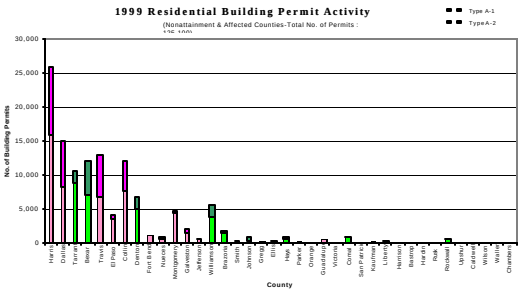

Figure 6: *1999 Residential building permits by county (Source: RECenter 2002). Type A-1 houses are single family residential. Type A-2 houses are multifamily residential.*

[8] This is indicated by the upper portion of each bar in Figure 3.

METHODOLOGY

The TCEQ is currently working with the EPA, through the Texas Emissions Reduction Plan (TERP) to obtain SIP emissions reduction credits for reductions in electricity use, with an emphasis on peak summertime electric demand, that are attributable to the adoption of the International Energy Conservation Code (IECC 2001) in non-attainment and affected counties. In order for the TCEQ to accomplish this county-wide reductions in electricity use must be calculated by the Energy Systems Laboratory and presented to the TCEQ in a suitable format for calculating emissions reductions using the EPA's Emissions and Generation Resource Integrated Database (E-GRID)[9]. The methodology to accomplish this for residential buildings is presented in Figure 7, additional detailed information can be found in Haberl et al. (2002a, 2002b, 2003). This methodology is composed of several procedures that calculate and verify savings using different sources of information.

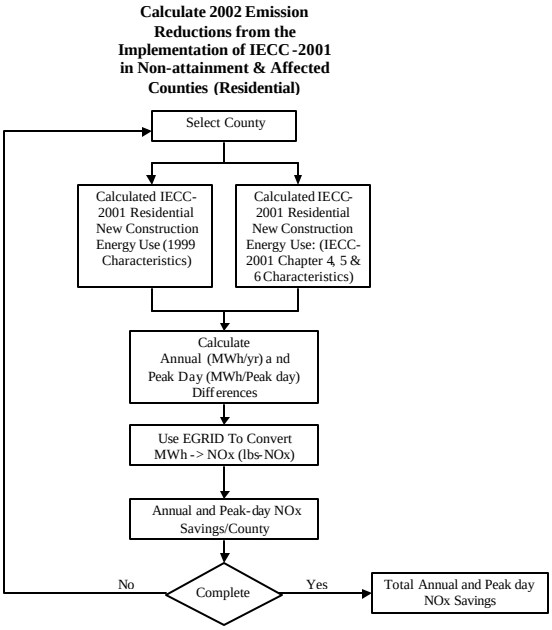

Figure 7: *Overall general flowchart for calculation of emission reductions from implementation of IECC/IRC 2001 in non-attainment and affected counties.*

These procedures include:

1. The calculation of electricity savings and peak-day electricity use reductions from the implementation of the IECC 2001 in new single-family residences in non-attainment and affected counties as compared against 1999 single-family housing characteristics using a calibrated DOE-2 simulation.
2. A cross-check of the calculated energy use against the published average energy use found in the USDOE's Residential Energy Characteristics Survey[10] (RECS 1999) and other data sources.
3. A cross-check of energy savings using monthly utility billing data from a sample of houses analyzed with the Princeton Scorekeeping Method (PRISM) (Fels 1986; Fels et al. 1995),
4. A cross-check of construction data using on-site visits.

Calculation of NO_x Emissions Reductions

For each county, 1999 and 2002 residential housing characteristics for single-family homes were ascertained, then using simulation, these characteristics are entered into a code-traceable DOE-2 simulation to calculate the annual energy use of two average-sized residences, one representing a prototypical single-family house with the average 1999 characteristics, and one representing the same house with specific new characteristics from the 2001 IECC[11]. For each county the 1999 single-family residential housing characteristics were obtained from the annual builder's survey performed by the National Association of Home Builders as shown in Table 2 (NAHB 2002)[12]. The average 1999 air-conditioner efficiencies (i.e., SEER 11) were obtained from the American Refrigeration Institute statewide sales data for Texas ARI (2002). Average furnace efficiencies and domestic water heater efficiencies were assumed to meet the Federal Standards of 80% and 76%, respectively. The 2001 IECC code-

[9] E-GRID, Ver. 2, is the EPA's Emissions and Generation Resource Integrated Database. This publicly available database can be found at www.epa.gov/airmarkets/egrid/.

[10] The energy use reported by RECS represents the total energy use, which would include electricity use and natural gas use.

[11] Due to limited resources, the results reported in 2002 were obtained using one prototypical house type based on NAHB survey data for Texas. Future efforts will be developing additional prototypical house types, including: fuel neutral heating, and DHW systems, one or two story houses, houses with crawl spaces or slab contruction, a duct model, and multifamily and commercial building prototypes, which will be constructed to be representative of the new building construction in Texas.

[12] The NAHB characteristics divided the state into east (E), and west (W) divisions: window-to-wall area E=15.28%, W=20.6%, glazing U-value E=1.11, W=0.87, SHGC E=0.66, W=0.71, roof R-value E=27.01, W=26.75, wall R-value E=13.99, W=14.18.

For Single Family

	County	Power Control Area[1]	Climate Zone[2]	No. of projected units[3]	Floor Area (ft2)[4]	1999 Average Energy Use (kWh)[5]	IECC 2001 Energy Use (kWh)[6]	Peak Date	1999 Peak Day(KWH/ House)[7]	IECC Peak Day(KWH/ House)[8]	Savings per house (kWh)[9]	Total Savings (MWh) 1999-IECC w/ 28% T&D Loss [10]	lb-NOx/MWh[11]	Total Savings Tons/Year[12]	Total Savings Tons/Day[13]	Peak Tons/Day[14]
Affected County	Bastrop	ERCOT	4	146	2,426	16,545	13,310	31-Jul	77.98	59.56	3,235	588.77	2.68	0.7823	0.0021	0.0036
	Bexar	San Antonio Public Service Bd	4	7,166	2,426	16,681	13,332	28-Aug	71.48	55.66	3,349	28,806.76	3.24	46.6659	0.1279	0.1637
	Caldwell	ERCOT	4	101	2,426	16,545	13,310	31-Jul	77.98	59.56	3,235	392.08	2.68	0.5274	0.0014	0.0025
	Comal	ERCOT	4	1,111	2,426	16,681	13,332	28-Aug	71.48	55.66	3,349	4,464.89	2.68	6.0053	0.0165	0.0236
	Ellis	TXU	5	649	2,426	15,465	12,448	29-Jul	82.47	61.45	3,017	2,349.64	3.34	3.9239	0.0108	0.0228
	Gregg	SWEPCO	6	194	2,548	13,139	11,258	22-Jul	66.34	52.74	1,881	437.90	2.68	0.5870	0.0016	0.0033
	Guadalupe	ERCOT	4	475	2,426	16,681	13,332	28-Aug	71.48	55.66	3,349	1,820.88	2.68	2.5837	0.0071	0.0102
	Harrison	SWEPCO	6	33	2,548	13,139	11,258	22-Jul	66.34	52.74	1,881	74.49	2.68	0.0999	0.0003	0.0006
	Hays	ERCOT	5	737	2,426	16,662	13,190	31-Jul	79.83	59.28	3,902	3,097.17	2.68	4.1557	0.0114	0.0184
	Johnson	TXU	5	629	2,426	15,465	12,448	29-Jul	82.47	61.45	3,017	2,277.29	3.34	3.8039	0.0104	0.0221
	Kaufman	TXU	6	218	2,426	15,725	12,419	19-Aug	78.10	58.40	3,306	854.85	3.34	1.4443	0.0040	0.0072
	Hussos	CRI	3	641	2,548	14,364	12,851	18-Aug	63.46	56.11	1,703	1,716.67	2.68	2.3039	0.0063	0.0063
	Parker	TXU	6	302	2,426	15,725	12,419	19-Aug	78.10	58.40	3,306	1,198.09	3.34	2.0238	0.0056	0.0099
	Rockwall	TXU	6	1,111	2,426	15,725	12,419	19-Aug	78.10	58.40	3,306	4,407.56	3.34	7.3806	0.0202	0.0366
	Rusk	SWEPCO	5	17	2,548	13,139	11,253	22-Jul	66.34	52.97	1,886	38.47	2.68	0.0516	0.0001	0.0003
	San Patricio	CRI	3	218	2,548	14,364	12,851	18-Aug	63.46	56.11	1,703	445.50	2.68	0.5972	0.0016	0.0021
	Smith	TXU	5	465	2,548	13,139	11,253	22-Jul	66.34	52.97	1,886	1,052.39	3.34	1.7575	0.0048	0.0095
	Travis	Austin Energy	5	5,822	2,426	16,662	13,190	31-Jul	79.83	59.28	3,502	24,806.61	1.44	17.8184	0.0491	0.0791
	Upshur	SWEPCO	6	17	2,548	13,139	11,258	22-Jul	66.34	52.74	1,881	38.37	2.68	0.0514	0.0001	0.0003
	Victoria	CRI	3	196	2,548	13,823	12,251	2-Sep	67.25	60.21	1,672	313.00	2.68	0.4196	0.0011	0.0015
	Williamson	TXU	5	4,111	2,426	16,662	13,190	31-Jul	79.83	59.28	3,902	17,276.07	2.68	23.1598	0.0634	0.1022
	Wilson	ERCOT	4	18	2,426	16,681	13,332	28-Aug	71.48	55.66	3,349	64.30	2.68	0.0865	0.0002	0.0003
Nonattain-ment County	Brazoria	Reliant Energy HL & P	3	2,005	2,548	13,740	11,858	29-Jul	66.52	55.566	1,881	4,532.46	1.88	4.2605	0.0117	0.0207
	Chambers	EGS	4	318	2,548	12,913	11,297	1-Sep	59.02	49.96	1,816	616.67	2.68	0.8266	0.0023	0.0039
	Collin	TXU	5	9,699	2,426	15,725	12,419	19-Aug	78.10	58.40	3,306	38,239.94	3.34	63.8805	0.1750	0.3172
	Dallas	TXU	5	8,595	2,426	15,465	12,448	29-Jul	82.47	61.45	3,017	31,117.34	3.34	51.9680	0.1424	0.3017
	Denton	TXU	6	5,336	2,426	15,725	12,419	19-Aug	78.10	58.40	3,306	21,176.91	3.34	35.3654	0.0969	0.1757
	El Paso	EL PASO Electric Company	6	3,099	2,426	16,085	12,684	12-Jul	76.74	59.62	3,401	12,643.56	2.68	16.9487	0.0464	0.0839
	Fort Bend	Reliant Energy HL & P	4	1,049	2,548	13,093	11,467	29-Jul	61.75	51.80	1,826	2,046.81	1.88	1.9240	0.0053	0.0098
	Galveston	Reliant Energy HL & P	3	2,335	2,548	13,740	11,858	29-Jul	66.52	55.566	1,881	5,277.33	1.88	4.9607	0.0136	0.0241
	Hardin	EGS	4	19	2,548	12,913	11,297	1-Sep	59.02	49.96	1,816	36.84	2.68	0.0494	0.0001	0.0002
	Harris	Reliant Energy HL & P	4	19,183	2,548	13,093	11,467	29-Jul	61.75	51.80	1,826	37,429.87	1.88	35.1841	0.0964	0.1795
	Jefferson	EGS	4	810	2,548	12,913	11,297	1-Sep	59.02	49.96	1,816	1,182.91	2.68	1.5857	0.0043	0.0074
	Liberty	EGS	4	313	2,548	12,913	11,297	1-Sep	59.02	49.96	1,816	413.05	2.68	0.5537	0.0015	0.0026
	Montgomery	EGS	4	4,032	2,548	13,093	11,467	29-Jul	61.75	51.80	1,826	7,867.24	2.68	10.5469	0.0289	0.0536
	Orange	EGS	4	172	2,548	12,913	11,297	1-Sep	59.02	49.96	1,816	333.54	2.68	0.4471	0.0012	0.0021
	Tarrant	TXU	5	10,398	2,426	15,465	12,448	29-Jul	82.47	61.45	3,017	37,800.10	3.34	62.6252	0.1716	0.3839
	Waller	Reliant Energy HL & P	4	22	2,548	13,093	11,467	29-Jul	61.75	51.80	2,047	54.04	1.88	0.0508	0.0001	0.0002
	TOTAL										2,517	297,160.32		417.4288	1.1436	2.0947

1. The Power Control Area is classified from Texas Electric Retail Service Area Map published by the Texas Public Utilities Commission.
2. The climate zones are from the IECC 2000 Chapter 3
3. No. of Projected Units: The data from Real Estate Center of TAMU and U.S. Census.
4. Floor Area: From NAHB Survey Data
5,6. 1999 & IECC 2000 Energy use: From the DOE-2 simulation (BEPS report).
7,8. Peak-day electricity use (kWh/Day): From the DOE-2 ps-f report and the corresponding hourly report of DOE-2.1e simulation. (i.e., Find the date of the peak day from the ps-f report and the peak day use from hourly report for that day).
9. Savings per house: 1999 average energy use - IECC 2000 energy use
10. Total Savings: Savings per house x No. of Projected Unit
11. lb-NOx/MWH: From the June 2002 TNRCC published values (EGRID). The average lb-NOx/MWH of Texas is 2.68
12. Tons/year: (Total Savings x lb-NOx/MWH)/2000
13. Tons/day: (Tons/year)/365
14. Peak Tons/day: (((1999 peak day use-IECC peak day use)/2000) x No. of Projected Unit x lb-NOx/MWH)/2000
15. TMY2: Classifed from the map of available weather files & weather station
16. Division (East and West Texas): From NAHB survey data.
17. AFUE (%),SEER and Water Heater Efficiency for 1999 standard and IECC 2000 house are 80%, 11 and 76%, respectively.

Table 1: *2002 NOx emissions reductions from implementation of the 2000 IECC to single-family residences in non-attainment and affected counties.*

Input Parameter													
	County	TMY2[15]	Division (East or West)[16]	1999 Average					IECC 2001				
				Area %	Glazing U-value	SHGC	Roof Insulation	Wall Insulation	Area %	Glazing U-value	SHGC	Roof Insulation	Wall Insulation
Affected County	Bastrop	Austin	West	23.69	0.87	0.66	26.75	14.18	23.69	0.52	0.40	30.00	13.00
	Bexar	San Antonio	West	23.69	0.87	0.66	26.75	14.18	23.69	0.52	0.40	30.00	13.00
	Caldwell	Austin	West	23.69	0.87	0.66	26.75	14.18	23.69	0.52	0.40	30.00	13.00
	Comal	San Antonio	West	23.69	0.87	0.66	26.75	14.18	23.69	0.52	0.40	30.00	13.00
	Ellis	Fort Worth	West	23.69	0.87	0.66	26.75	14.18	23.69	0.50	0.40	38.00	13.00
	Gregg	Lufkin	East	15.28	1.11	0.71	27.08	13.99	15.28	0.60	0.40	30.00	13.00
	Guadalupe	San Antonio	West	23.69	0.87	0.66	26.75	14.18	23.69	0.52	0.40	30.00	13.00
	Harrison	Lufkin	East	15.28	1.11	0.71	27.08	13.99	15.28	0.60	0.40	30.00	13.00
	Hays	Austin	West	23.69	0.87	0.66	26.75	14.18	23.69	0.50	0.40	38.00	13.00
	Johnson	Fort Worth	West	23.69	0.87	0.66	26.75	14.18	23.69	0.50	0.40	38.00	13.00
	Kaufman	Fort Worth	West	23.69	0.87	0.66	26.75	14.18	23.69	0.46	0.40	38.00	16.00
	Nueces	Corpus Chrsti	East	15.28	1.11	0.71	26.75	14.18	15.28	0.75	0.40	19.00	11.00
	Parker	Fort Worth	West	23.69	0.87	0.66	26.75	14.18	23.69	0.46	0.40	38.00	16.00
	Rockwall	Fort Worth	West	23.69	0.87	0.66	26.75	14.18	23.69	0.46	0.40	38.00	16.00
	Rusk	Lufkin	East	15.28	1.11	0.71	27.08	13.99	15.28	0.65	0.40	30.00	13.00
	San Patricio	Corpus Chrsti	East	15.28	1.11	0.71	26.75	14.18	15.28	0.75	0.40	19.00	11.00
	Smith	Lufkin	East	15.28	1.11	0.71	27.08	13.99	15.28	0.65	0.40	30.00	13.00
	Travis	Austin	West	23.69	0.87	0.66	26.75	14.18	23.69	0.50	0.40	38.00	13.00
	Upshur	Lufkin	East	15.28	1.11	0.71	27.08	13.99	15.28	0.60	0.40	30.00	13.00
	Victoria	Victoria	East	15.28	1.11	0.71	26.75	14.18	15.28	0.75	0.40	19.00	11.00
	Williamson	Austin	West	23.69	0.87	0.66	26.75	14.18	23.69	0.50	0.40	38.00	13.00
	Wilson	San Antonio	West	23.69	0.87	0.66	26.75	14.18	23.69	0.52	0.40	30.00	13.00
Nonattain-ment County	Brazoria	Houston	East	15.28	1.11	0.71	26.75	14.18	15.28	0.75	0.40	19.00	11.00
	Chambers	Port Arthur	East	15.28	1.11	0.71	27.08	13.99	15.28	0.75	0.40	26.00	13.00
	Collin	Fort Worth	West	23.69	0.87	0.66	26.75	14.18	23.69	0.46	0.40	38.00	16.00
	Dallas	Fort Worth	West	23.69	0.87	0.66	26.75	14.18	23.69	0.50	0.40	38.00	13.00
	Denton	Fort Worth	West	23.69	0.87	0.66	26.75	14.18	23.69	0.46	0.40	38.00	16.00
	El Paso	El Paso	West	23.69	0.87	0.66	26.75	14.18	23.69	0.46	0.40	38.00	16.00
	Fort Bend	Houston	East	15.28	1.11	0.71	27.08	13.99	15.28	0.75	0.40	26.00	13.00
	Galveston	Houston	East	15.28	1.11	0.71	26.75	14.18	15.28	0.75	0.40	19.00	11.00
	Hardin	Port Arthur	East	15.28	1.11	0.71	27.08	13.99	15.28	0.75	0.40	26.00	13.00
	Harris	Houston	East	15.28	1.11	0.71	27.08	13.99	15.28	0.75	0.40	26.00	13.00
	Jefferson	Port Arthur	East	15.28	1.11	0.71	27.08	13.99	15.28	0.75	0.40	26.00	13.00
	Liberty	Port Arthur	East	15.28	1.11	0.71	27.08	13.99	15.28	0.75	0.40	26.00	13.00
	Montgomery	Houston	East	15.28	1.11	0.71	27.08	13.99	15.28	0.75	0.40	26.00	13.00
	Orange	Port Arthur	East	15.28	1.11	0.71	27.08	13.99	15.28	0.75	0.40	26.00	13.00
	Tarrant	Fort Worth	West	23.69	0.87	0.66	26.75	14.18	23.69	0.50	0.40	38.00	13.00
	Waller	Houston	East	15.28	1.11	0.71	27.08	13.99	15.28	0.75	0.40	26.00	13.00

Table 2: *Input Variables for the Calculation of 2002 NOx Emissions Reductions.*

compliant housing characteristics were then determined for a house with an equivalent floor area and an equivalent window-to-wall area[13]. In this analysis, it was assumed that all houses have air conditioning, and natural gas heating and DHW, which represents the most common single-family house according to the 1999 NAHB survey. All other characteristics in the simulation were carefully chosen to match the requirements of Chapter 4 of the 2001 IECC[14]. To accommodate the simulation of varying floor areas, a scaleable simulation file was created as shown in Figure 8, which shows a 1,000 ft^2 house in the upper portion of the figure and a 5,000 ft^2 house in the lower portion of the figure[15].

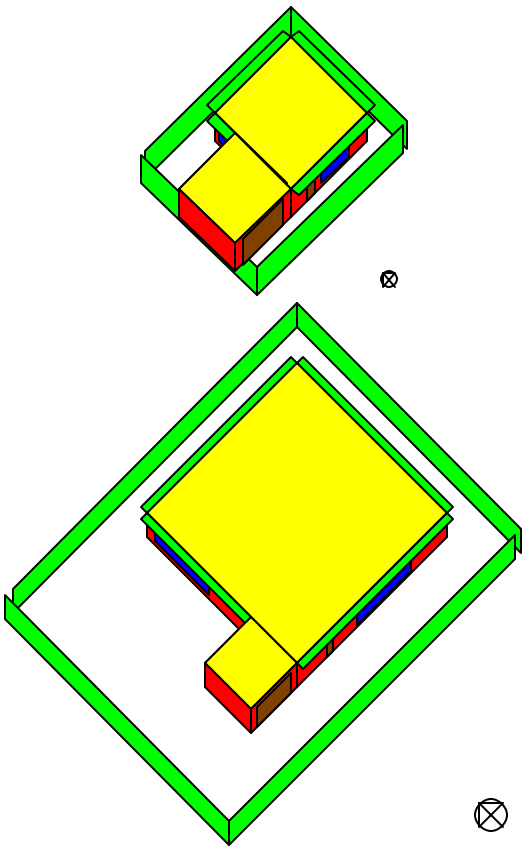

Figure 8: *Architectural rendering of the prototypical 2000 IECC single-family residence (Upper: 1,000 ft^2, Lower: 5,000 $ft^{2)}$.*

The procedure for linking the county-wide electricity reductions calculated with the DOE-2 simulations to the EPA's E-GRID program (E-GRID 2002) are shown in Figure 9, additional details can be found in Haberl et al. (2003). In this procedure, the code-traceable DOE-2 simulation is used to calculate the annual electricity savings (kWh/yr) and peak-day electricity savings (kWh/day) from the implementation of the 2001 IECC for all houses built in a county. The utility supplier for each county is then assigned according to data published by the Texas Public Utilities Commission (TPUC 2003). For each utility supplier E-GRID then calculates, on average, which utility plant supplied electricity including which counties those plants were located in, and the associated NO_x, SO_2, CO_2 and mercury emissions. The emissions from the different power plants in each county are then totaled to give the total county-wide emissions.

[13] These were determined using the appropriate IECC climate zone for each county and the window-to-wall area that corresponded to the NAHB survey data. For more information see the Texas Builder's Prescriptive Compliance Form located at "eslsb5.tamu.edu". The code-traceable simulation can be viewed at "eslsb5ec.tamu.edu". For example, in Harris County, the IECC-compliant house has 15.28% window-to-wall area, 0.75 glazing U-value, SHGC = 0.40, roof R-value of 27.08 (i.e., the same as the NAHB house), wall R-value of 13.99, SEER = 10, AFUE = 0.80, and DHW = 0.76. Additional information about these characteristics can be found in Haberl et al. (2003).

[14] The standard house is a one story square house facing west with an uninsulated slab on grade foundation. Interior walls are 8 feet in height. There are no exterior shading devices, moveable windows shades or adjacent buildings or shade trees. A garage is attached on the north side of the house, and the house has two exterior doors (front and back). The solar absorptance is assumed to be 0.55 for the exterior walls and 0.50 for the roof. The window frames are aluminum w/o thermal break, no dividers. The edge of glass U-factor is not included in the calculation. The roof is flat with no penalty for duct loss. The heating and cooling equipment are automatically sized by the DOE-2.1e, Version 119 simulation. The thermostat is programmable with customized settings according to IECC 2001 with 68F for heating and 78F for cooling and 5F setback for 6 hours. Water heating is natural gas. Total daily consumption is given by: gal/day= (30xa)+(10xb), where a = number of living units in the standard and proposed design, b = number of bedrooms in each living. The number of bedroom was fixed for all simulations. Infiltration is calculated according to ASHRAE Standard 136. Equipment efficiency for the 1999 and 2001 IECC standard house assumed to be AFUE = 80%, SEER= 11, and the Water Heater Efficiency = 76% (i.e., According to the NAHB the existing housing stock already contained equipment in compliance with the 2001 IECC).

[15] In this figure, rendered with the DrawBDL program (Huang 2002), two potential types of shading are shown, shading from the eaves of the house and shading from nearby structures (i.e., the fence-like structure surrounding the house). In the calculations performed for this study, the transmittance of these shades were set equal to unity (i.e., transparent). However, the presence of the shade s remains in the DrawBDL rendering.

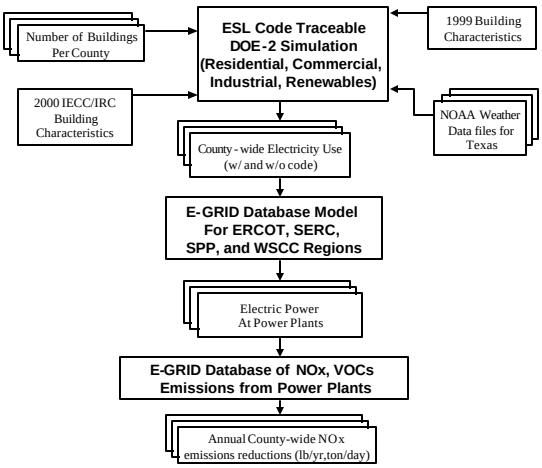

Figure 9: *Overall general flowchart for calculation of emission reductions from implementation of IECC/IRC 2001 in non-attainment and affected counties.*

Results: 2002 Emissions Reductions From the Implementation of the 2001 IECC to Single-Family Residential

Calculated NO_x emissions reductions from the implementation of 2001 IECC to single-family residences in 2002 can be seen in Table 1, and Figure 10 through Figure 13. Each row in the table represents an affected or non-attainment county, and contains information by column about the Power Control Area[16], the designated 2001 IECC Climate zone[17], the number of projected housing units[18], the simulated 1999 electricity use for an average house, the simulated electricity use of a house that is compliant with the 2001 IECC, the peak date of the electricity use on the TMY2 file used for the simulation, the daily electricity use on the peak day for the 1999 house and the 2001 IECC code-compliant house, the annual kWh savings for an average house, the total county-wide electricity savings for all houses built in the county, the PCA-average NO_x /MWh emissions factor assigned to the primary utility supplier for each county, and the NO_x savings for each year (tons/year and tons/peak-day). Electricity savings from the 2001 IECC code implementation average 11% to 20% of the annual electricity use, and of importance to ozone-plagued cities, a 11% to 23% reduction in peak daily electricity use[19], which equates to about 2 tons of NO_x /peak-day for single-family residential. Figure 10 shows the geographic distribution of the calculated electricity savings (upper map, MWh/day), and E-GRID calculated emissions reductions (lower map, peak tons- NO_x /day). Figure 11 shows the peak-day electricity savings by county.

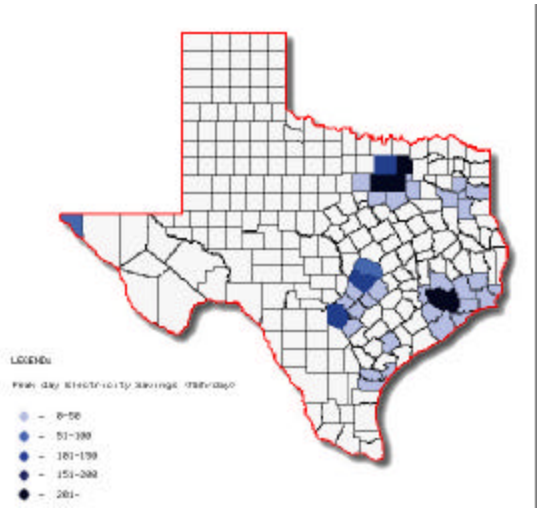

Figure 10: *Distribution of 2002 Peak-day Electricity Savings Due To the 2000 IECC (Single Family Residential)*

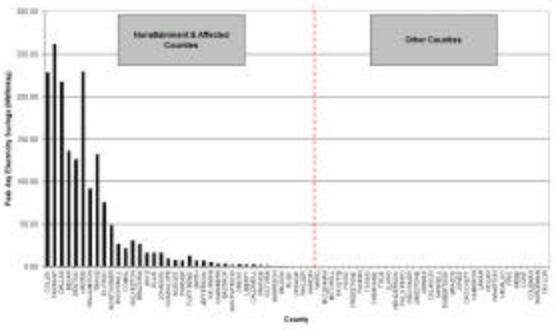

Figure 11: *2002 Peak-day Electricity Savings Due To the Implementation of the 2000 IECC (Single Family Residential).*

Several features are worth noting in Figure 10. First, in the map, as expected, the counties that experience the largest reductions in electricity use

[16] The Power Control Area represents the primary utility supplier to a particular county, secondary and tertiary suppliers are not listed. Counties listed as ERCOT were counties that were not assigned to a specific Power Control Area. Counties with ERCOT listed as the provider used an average emissions rating.

[17] The IECC climate zones shown include, climate zone 2 (500 – 999 HDD_{65F}) , zone 3 (1,000 – 1,499 HDD_{65F}), zone 4 (1,500 – 1,999 HDD_{65F}), zone 5 (2,000 – 2,499 HDD_{65F}), and zone 6 (2,500 – 2,999 HDD_{65F}).

[18] The number of projected single-family housing units for 2002 was determined using a linear projection of the housing growth from the three previous years.

[19] The majority of these simulated savings appear to be related to the improved windows.

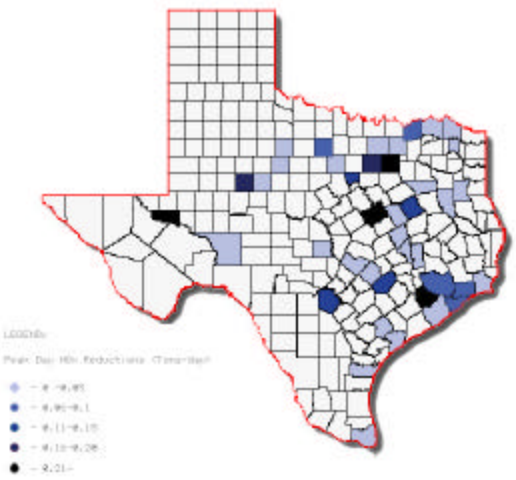

Figure 12: *Distribution of 2002 Peak-day NOx Emissions Reductions at the Power Plant due to the 2000 IECC (Single Family Residential).*

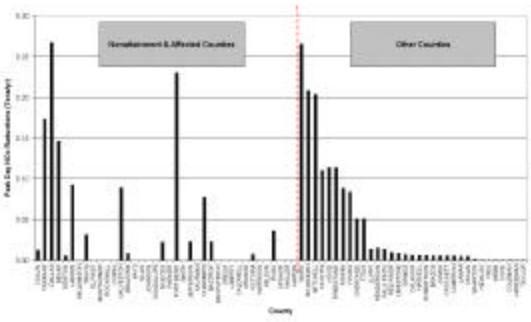

Figure 13: *Power Plant Peak-day NOx Reductions Due To The 2000 IECC (Single Family Residential)*

correspond to the counties with the most construction. However, of importance to emissions reductions, the reductions of NO_x at the power plant occurs in counties that may not be experiencing the most construction (Figure 12). For example, in the Houston area, Ft. Bend county is calculated to have 0.23 tons NO_x /peak-day reduction because this county contains a very large power plant for the major utility that serves this region. However, Ft. Bend county has only modest construction growth. In contrast to this is the Dallas/Ft. Worth area contains two counties (i.e., Dallas and Tarrant) that contain power plants and significant new construction activity. Therefore, the combined DOE-2/E-GRID analysis provides the state's pollution decision makers with a new tool for deciphering not only where the pollution reductions are coming from but also where the electricity reductions are coming from – important information for rule-making legislators as well. Figure 13 shows the peak-day NO_x reductions by county as calculated by EGRID.

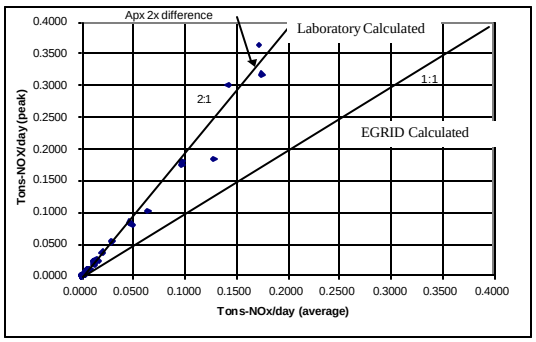

Figure 14: *Comparison of Peak Day Versus Average Daily NOx Reductions for the 38 Non-attainment and Affected Counties.*

Finally, Figure 14 has been provided to show the importance of calculating peak-day NO_x reductions. In Figure 14 the DOE-2 simulation was used to identify the peak-day electricity use using the appropriate TMY2 weather file. These peak-day electricity savings were then calculated for each house and then multiplied by the number of expected new housing starts in each county[20]. In a similar fashion to the annual reductions, the peak-day electricity reductions were then fed into the EGRID database to calculate the NO_x emission reductions at the power plant that served that county. The approximate 2:1 difference between the calculation of peak-day emissions vs average daily emissions[21] illustrates the importance of the use of peak-day vs average daily NO_x reduction calculations[22].

SUMMARY

In 2001, the Texas State Legislature formulated and passed Senate Bill 5 to reduce ozone levels by encouraging the reduction of emissions of NO_x . This paper has outlined the methodology that was developed to report the electricity savings

[20] This assumes a 100% diversity factor for peak conditions, an assumption that will need to be verified in future work.

[21] Average daily emissions were first proposed by the TNRCC to the EPA for accounting for the NOx reductions from electricity savings from the 2000 IECC. These emissions are calculated by dividing the annual total emissions by 365.

[22] Similar peak-day procedures will need to be developed for other emissions reductions from electricity use reductions in commercial, industrial and municipal sectors.

associated with the adoption of the 2001 IECC in single-family residential construction in non-attainment and affected counties. These electricity savings were converted to NO_x reductions using the EPA's E-GRID database, which contains a state-wide, utility grid conversion model. This methodology is composed of several procedures that calculate and verify savings using different sources of information. These procedures include the calculation of electricity savings from the implementation of the IECC 2001 in new residences in non-attainment and affected counties using a code-traceable DOE-2 simulation, and the EPA's E-GRID database for assigning the reduced electricity use to power plants and the associated emissions reductions. Results were presented for the application of the methodology to single-family residential construction in 2002. The results from the application of the methodology have yielded valuable information for the state's environmental pollution control planners, whose ultimate goal is to work with EPA to obtain SIP emissions reduction credits from energy conservation measures in newly constructed buildings.

Future work includes the development of fuel-neutral, multi-story single family, multi-family and commercial code-traceable DOE-2 simulations and the development of procedures to feed the county-by-county, simulated hourly outputs of emissions reductions into the state's photochemical model for modeling the reductions during the 2000 episode day[23]. Efforts are also underway to develop procedures for calculating NO_x emissions reductions from the installation of renewable energy systems (i.e., solar thermal and photovoltaic), reductions of electricity use in existing buildings (i.e., retrofits), and reductions in electricity use from the municipal infrastructure that serves them (i.e., installation of efficient street lights, water supply and sewage treatment equipment).

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[23] Currently, the TCEQ is using the National Center for Atmospheric Research's MM5 meteorological model, which feeds data into the Comprehensive Air Quality Model with extensions (CAMx) model for simulating the photochemical reactions that produce ozone on the states non-attainment and affected counties (Nobel et al. 2001).

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